PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION
No. 28993 A.D. 1949.

Improvements in or relating to the Production of Electrical Resistors

We, WARD, BLENKINSOP & COMPANY LIMITED, a British Company, of 6, Henrietta Place, London, W. 1, PETER PAUL HOPF, a British Subject, and RONALD EDGAR JOHN LISHMUND, a British Subject, both of the Company's address, do hereby declare the nature of this invention to be as follows:—

This invention relates to improvements in or relating to the production of electrical resistors.

In some types of electrical apparatus it has become the practice to deposit the wiring and some of the components such as resistors and capacitors directly on to the base-plate or chassis thereof, and the circuits so formed have become known as "Printed Circuits."

Several methods have been used for depositing the wiring of printed circuits and these usually consist in depositing silver or copper onto the base-plate or chassis. The resistors used in such circuits have hitherto been formed by painting on the chassis a film, which will give a lower value of resistance than that required, and then scratching out or otherwise removing part of the film until the desired value of resistance is obtained. The paint used in the above-described process has usually consisted of materials which are poor electrical conductors, mixed in a cold-setting varnish or lacquer, for example, one such paint consists of colloidal graphite in a solution of shellac. These resistors have to be applied individually and have to be individually adjusted thus considerably increasing production costs.

The value of the resistance of the resistor thus applied to the chassis as part of the printed circuit is conveniently expressed and is represented by the formula

$$R = \rho \frac{.L}{W\ .T}$$

where R is the resistance in omhs, ρ is the specific resistance of the material used, L is the length, W is the width and T the thickness thereof. When L and W are equal i.e. the resistance is a square, R is independent of the area but varies with the thickness. Consequently the resistance can be expressed in ohms per square irrespective of the size of the square. In the method of obtaining resistors above described it is very difficult to obtain coatings of paint of even and predetermined thickness and it is clear from the formula that even slight variations in the value of T, which is usually a quantity of some few thousands of an inch or less, will considerably affect the value of R and, further, in order to produce a satisfactory resistor, the values of ρ and T must be constant throughout the film constituting the resistor. The usual manner of forming a film of predetermined thickness is to print through silk by the method known as silk-screen printing but even this process cannot be regarded as giving accurate results, since unevenness of deposit still occurs thus giving rise to inconsistency in the values of ρ and T.

One of the objects of the present invention is, therefore, to provide resistors which are easily reproducible in even and predetermined thickness and the material of which has a substantially constant value of resistance per unit surface area and which are particularly suitable for use in printed circuits.

Another object of the present invention is to reduce the cost of production of a printed circuit by providing resistors which are easily reproducible, have accurate required values of resistance and are simple to apply to the base-plate or chassis upon which a circuit is printed.

The present invention provides a method of producing an electrical resistor which

comprises applying to the surface of a plastic material form, the plastic material being of low moisture absorption and low conductivity, a composition containing an electrical conducting material and an alcohol in a substantially uniform pattern.

In a preferred form of the invention the pattern is in the form of a grid printed on to the plastic material. A conducting material such as graphite or carbon black, a powdered metal or metal oxide or non-water soluble metal salt is prepared in the form of a printing ink by mixing with an alcohol to give a suitable consistency. This ink is used in any known system of printing such as letter press, offset-litho or transfer methods, but the off-set transfer method is preferred. In this method a metal block is prepared of the grid system such as is provided by the negative of a half tone block. By automatic action of the offset press the block is inked up with the ink containing the electrical conductor and the image of the block transferred in ink on to a rubber blanket stretched on to a roller. This roller transfers or prints the image on to a plastic material film having the above mentioned electrical properties. This film is preferably an half thousandth of an inch in thickness, but may be thicker. Preferred plastic materials are high molecular weight or low molecular weight polystyrene, plasticised rubber, cellulose acetate polyethylene or polytetrafluoroethylene. The thus formed print may be dried by gentle heating and if water-soluble ingredients which are non-volatile have been used in the ink the print is then washed and dried. The print may also be subjected to heat and pressure simultaneously to ensure absolute evenness of distribution of the conducting particles.

In this manner substantially uniform prints are produced, and such errors as may exist are evened out by distribution of the error over a number of lines in the printed grid.

As the dimension of length of the resistor is usually determined by the circuit lay-out only the width may be varied to give the desired individual resistor. The printed sheet of plastic material thus produced has a fixed resistance per square from which, by variation of width, the desired resistor may be cut out and placed into the printed circuit: this may be accomplished by the use of adhesives or softening of the surface of the plastic material upon which the circuit may have been printed, or by any desired method, such as rivetting.

The following example illustrates the manner in which the invention may be carried into effect:

A negative half tone grid system having 100 lines per inch is printed using a transfer-offset press on to a polystyrene film using a printing ink consisting of 80 parts by weight of reduced iron powder suspended in 10 parts of ethanol and 10 parts of water. The resulting film is air dried and subjected to a temperature of 80° C. for a short time. This gives a resistance of approximately 100 ohms per square.

Resistances having any desired value may then be made by cutting out pieces of this material and these may be inserted between two conductive points in a printed circuit with the conductive side face downwards on the chassis and the resistance rivetted to the conductive terminals of the circuit.

STEVENS, LANGNER, PARRY & ROLLINSON,
Chartered Patent Agents,
Agents for the Applicants.

PROVISIONAL SPECIFICATION
No. 17664 A.D. 1949.

Improvements in or relating to the Production of Electrical Conducting Layers upon Insulating Surfaces

We, WARD, BLENKINSOP & COMPANY LIMITED, a British Company, of 6, Henrietta Place, London, W.1, PETER PAUL HOPF, a British Subject, and RONALD EDGAR JOHN LISHMUND, a British Subject, both of the Company's address aforesaid, do hereby declare the nature of this invention to be as follows:—

This invention relates to the production of printed electrical components and printed circuits.

During the past few years an increasing demand for printed circuits has arisen as their potentialities have been more fully appreciated and the methods of producing them have improved.

Several methods for producing printed circuits have been described. One is by painting the circuit on to the base material using a suitably pigmented paint: the painting may be done through

a stencil. A variant thereof is to spray molten metal. Deposition of metal through a stencil as a result of simultaneously spraying separately prepared solutions of suitably reacting chemicals has also been used. Metal spattering through stencils has been proposed.

In yet another type of process a foil of metal is bonded on to the base material and after applying a resist to those parts of the metal surface in which a conductor is required the remaining metal is etched away and the resist then removed. The usual bonding material employed as a thermo-setting adhesive. A variant of this is a transfer process using a paper coated with pigment and resin, involving a hot stamping operation.

In operating any process of this character it is important to obtain a uniform product with a minimum of rejects and in most of the known processes it has been found that there are various difficulties which lead to lack of uniformity and consequently the proportion of rejects is fairly high.

In our specification No. 14865/49 Serial No. 672.255 we have described one method for printing electrical components and printed circuits upon organic electrical insulating materials in which a high degree of uniformity in the product is obtainable, which is simple to control and in which overprinting can be carried out.

We have now found a further method by which this result can be achieved.

According to the present invention there is provided a process for producing a printed circuit and electrical components which comprises applying to the surface of an organic, electrical insulating material a pattern of the circuit or component as a coating, free from a permanent binder, of a finely divided electrical conductor and thereafter applying heat and pressure to at least the coated areas, the temperature pressure, and time employed being sufficient to cause the conductor to cohere together and to become at least partially embedded in the underlying material.

The starting materials employed in the present process are a finely divided form of the conductor such as finely divided silver or carbon. This is made up into a slurry in a volatile diluent to which may be added a small proportion of a less volatile organic solvent which may act as a temporary adhering agent. Examples of suitable diluents are the lower alkanols, especially methanol and ethanol, the cyclic ethers such as dioxane the lower aliphatic ketones such as acetone and methyl ethyl ketone, and water. In selecting the diluent regard must be had for any undersirable action, such as a swelling action, which it might have upon the surface of the insulating material. Typical examples of conductors useful in the process are finely divided silver obtained by filtering and washing the composition prepared according to the copending cognate applications No. 26892/46 and 10203/47, Serial No. 638,149, finely divided copper, carbon black and colloidal graphite. Examples of less volatile organic solvents which may be present in the slurries are the lower polyhydric alcohols, such as ethylene glycol and glycerine and the amino-alcohols, such as monoethanolamine. The proportion by weight of solids in the slurry varies greatly depending upon the material. In the case of finely divided silver the proportion may be about 4 to 1 whilst with carbon black 1 to 1 is suitable.

The organic electrically insulating material may be a thermoplastic or thermoset material or it may be a high polymer. Examples of suitable materials are electrical grades of phenol-formaldehyde and aniline-formaldehyde synthetic resins, polyacrylic resins, such as polymethyl methacrylate, polyvinyl resins, such as polystyrene and polythene. These materials may be used in a variety of form such as sheets, films, plates and blocks.

In describing one form of the invention it will be assumed that it is desired to produce a printed circuit in silver upon a phenol-formaldehyde sheet material. A stencil is prepared whose cut out portions correspond to the outline of the circuit. The stencil is applied to one surface of the sheet material, which may have had any holes that are desired punched into it. The stencil-covered surface is then sprayed with a slurry of sponge silver in methanol and the stencil then removed leaving a pattern corresponding to that of the printed circuit that it is desired to produce. The greater part of the methanol is then removed by drying, a small amount being retained for adhering the silver to the sheet. The sheet is then placed in a press which has a heated platen and the platen is then brought into contact with the surface carrying the pattern. It is preferred to apply the maximum possible pressure and to use the lowest possible temperature in this operation, and, in general times of the order of 1—10 seconds are used. With a phenol-formaldehyde insulating material a pressure of about 1000 lbs./in.^{2} at about 200° C. and a contact time of 4 seconds has been found suitable.

Instead of using a press the sheet material may be passed between a pair of rollers one of which is heated, as described in application No. 16867/49. Serial No. 672,260.

Materials having a fairly well defined melting point, such as polythene, may be printed with the platen run at a temperature somewhat above the melting point provided that the time of contact is short.

With thermoset materials quite high temperatures, such as 200—250° C. and high pressures such as 1000—2000 lbs./in.^{2} are preferred. Materials which soften on heating may be printed using a plate maintained at a much higher temperature than that at which they first soften.

When using a thermoplastic material or a material like polythene which has a definite and rather low melting point it is preferred, prior to applying heat and pressure, to interpose a thin sheet of paper which absorbs organic liquids and provides a path for the escape of vapours as well as protecting areas to which heat and pressure is not to be applied.

The pattern of the component or circuit need not be produced on the insulating material using a stencil. Other methods, such as offset printing may be used.

When a printed circuit has been produced in the manner described above the spaces that have been left for resistors can be overprinted. The procedure already described is then repeated using a second stencil whose cut-out portions correspond to the outline of the resistors. This stencil is applied, in register, to the once printed sheet and a graphite slurry then sprayed on. The cut-out portions should provide for slight overlap onto the conductors at the appropriate points in order to provide contacts. The further procedure is the same as for printing the silver circuit.

Not only complete circuits but specific components such as coils can be printed in the manner described.

The present process, like that of application No. 672,255 requires that the conductor be applied to the surface of the insulating material without a permanent binder being present. A small amount of higher boiling organic liquid or the residue of the volatile diluent being relied upon to maintain a sufficient adherence of the particles of the conductor to the insulating material and this is volatilised when heat and pressure are applied. In the product the particles firmly cohere to each other and at least the lower layers thereof are finely embedded in the insulating material.

The higher boiling organic liquid may be so chosen as to counteract any tendency of the conductor to undergo chemical change in the earlier stages of the process. Thus when sponge silver is used a small addition of an ethanolamine may be made to prevent oxidation to silver oxide or to reverse such change, if this has occurred, during the hot pressing. However since the reduction involved is an exothermic process it is not possible to use silver oxide *per se* in the coating step.

Different circuits may be printed upon the two sides of the insulating material. The second side may have an electronic shield printed thereon which may be produced according to copending application No. 672,260.

The following Examples illustrate the manner in which the invention may be carried into effect:

Example 1.

A block is prepared of a circuit to be printed and mounted on an off-set press having a rubber sheet for transfer. The block is inked with a slurry consisting of 70% by weight of finely divided silver, 20% of triethanolamine alginate and 10% of ethylene glycol. The slurry is transferred in the usual way for off-set printing on to a sheet of polystyrene. The print is now sprinked with finely divided silver, then with french chalk and brushed with a sable brush. The printed sheet is covered with a sheet of very fine rag paper and inserted in a press, the platen of which is run at 150° C. and the pressure being about 500 lbs./in.^{2} and pressed for 0.5 second. The sheet is then removed from the press and is washed with water.

Example 2.

A pattern of a printed circuit is applied to an electrical grade of a phenol-formaldehyde laminate by the silk screen method using a slurry containing 70% by weight of finely divided silver, 5% of monoethanolamine and 25% of methanol. The print is partially dried by infra-red heating, placed in a press and subjected to a temperature of 210° C. and 1000 lbs./in.^{2} for 4 seconds. The laminate is removed and washed.

To apply the resistors to this circuit it is printed a second time by the silk screen process the stencil employed having been cut out to leave the resistor areas uncovered and allow slight overlap on to the appropriate portions of the conductors. The slurry used is 20% by weight of carbon black, 5% of glycerine and 75% of methanol. The print is partially dried, placed in the press, covered with a sheet of very fine rag paper and then given the same temperature, pressure and time treatment as previously. The sheet is then taken out of the press and washed.

Dated the 4th day of July, 1949.

For:
WARD, BLENKINSOP & COMPANY LIMITED, PETER PAUL HOPF and RONALD EDGAR JOHN LISHMUND,
Stevens, Langner, Parry & Rollinson,
Chartered Patent Agents,
5 to 9, Quality Court, Chancery Lane,
London, W.C.2, and at
120, East 41st. Street, New York, 17,
N. Y., United States of America.

COMPLETE SPECIFICATION

Improvements in or relating to the Production of Electrical Conducting Layers upon Insulating Surfaces

We, WARD, BLENKINSOP & COMPANY LIMITED, a British Company, of 6, Henrietta Place, London, W.1, PETER PAUL HOPF, a British Subject, of the Company's address, and RONALD EDGAR JOHN LISHMUND, a British Subject, of the Company's address, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to the production of printed electrical components and printed circuits.

During the past few years an increasing demand for printed circuits has arisen as their potentialities have been more fully appreciated and the methods of producing them have improved.

Several methods for producing printed circuits have been described. One is by painting the circuit on to the base material using a suitably pigmented paint: the painting may be done through a stencil. A variant thereof is to spray molten metal. Deposition of metal through a stencil as a result of simultaneously spraying separately prepared solutions of suitable reacting chemicals has also been used. Metal spattering through stencils has been proposed.

In yet another type of process a foil of metal is bonded on to the base material and after applying a resist to those parts of the metal surface in which a conductor is required the remaining metal is etched away and the resist then removed. The usual bonding material employed is a thermo-setting adhesive. A variant of this is a transfer process using a paper coated with pigment and resin, involving a hot stamping operation.

In operating any process of this character it is important to obtain a uniform product with a minimum of rejects and in most of the known processes it has been found that there are various difficulties which lead to lack of uniformity and consequently the proportion of rejects is fairly high.

According to the present invention there is provided a process for producing a printed electrical element which comprises applying to the surface of an organic electrically insulating material a pattern of an electrical conducting path as a coating, substantially free from any permanent binder, of a finely divided electrical conductor and thereafter simultaneously applying heat and pressure to at least the coated areas whereby the individual particles of conducting material cohere together to form said conducting path at least partially embedded in the underlying insulating material.

The starting materials employed in the present process are a finely divided form of the conductor such as finely divided silver or carbon. This is made up into a slurry in a volatile diluent to which may be added a small proportion of a less volatile organic solvent which may act as a temporary adhering agent. Examples of suitable diluents are the lower alkanols, especially methanol and ethanol, the cyclic ethers such as dioxane, the lower aliphatic ketones, such as acetone and methyl ethyl ketone, and water. In selecting the diluent regard must be had for any undesirable action, such as a swelling action, which it might have upon the surface of the insulating material. Typical examples of conductors useful in the process are finely divided silver obtained by filtering and washing the composition prepared according to the copending cognate British applications Nos. 26892/46 (Serial No. 638.149) and 10203/47. (Serial No. 638.149) finely divided copper, carbon black and colloidal graphite. Examples of less volatile organic diluents

which may be present in the slurries are the lower polyhydric alcohols, such as ethylene glycol and glycerine and the amino-alcohols, such as monoethanol amine. The proportion by weight of solids in the slurry varies greatly depending upon the material. In the case of finely divided silver the proportion may be about 4 to 1 whilst with carbon black 1 to 1 is suitable.

The organic electrically insulating material may be a thermoplastic or thermoset material or it may be a high polymer. It may also be loaded with inorganic insulating materials such as asbestos, silica or glass fibres. Examples of suitable materials are electrical grades of phenol-formaldehyde and aniline-formaldehyde synthetic resins, polyacrylic resins, such as polymethyl methacrylate, polyvinyl resins, such as polystyrene and polythene. These materials may be used in a variety of forms such as sheets, films, plates and blocks. A film may be carried upon a supporting base and may be produced thereupon by coating. Such film may be more highly polymerized or condensed to the form having the most favourable electrical properties by the action of heat or actinic light. Such polymerization or condensation may be carried out at any convenient stage after coating the film. Such step may be carried out in two or more stages i.e. partial curing prior to applying the conductor followed by a second partial curing after the conductor has been set.

In describing one form of the invention it will be assumed that it is desired to produce a printed circuit in silver upon a phenol-formaldehyde sheet material. A stencil is prepared whose cut out portions correspond to the outline of the circuit. The stencil is applied to one surface of the sheet material, which may first have had any holes that are desired punched into it. The stencil-covered surface is then sprayed with a slurry of sponge silver in methanol and the stencil then removed leaving a pattern corresponding to that of the printed circuit that it is desired to produce. The greater part of the methanol is then removed by drying, a small amount being retained for adhering the silver to the sheet. The sheet is then placed is a press which has a heated platen and the platen is then brought into contact with the surface carrying the pattern. It is preferred to apply the maximum possible pressure and to use the lowest possible temperature in this operation, and in general times of the order of 1—10 seconds are used. With a phenol-formaldehyde insulating material and a pressure of about 1000 lbs./in.^{2} at about 200° C. and a contact time of 4 seconds has been found suitable.

Instead of using a press the sheet may be passed between a pair of rollers, the one in contact with the coated surface being heated. The pressure at the nip of the rollers should be adjustable to any desired value. It is preferred to apply the maximum possible pressure and the lowest possible temperature in this operation. If desired, the coated surface can be preheated, as by radiant heat, immediately prior to passing to the rollers, but if this is done it may be necessary to displace the atmosphere in contact with the coated surface so as to prevent oxidation: nitrogen is suitable for this purpose.

With thermoset materials quite high temperatures, such as 200—250° C., and high pressures such as 1000—2000 lbs./in.^{2} are preferred. Materials which soften on heating may be printed using a platen maintained at a much higher temperature than that at which they first soften.

When using a thermoplastic material or a material like polythene which has a definite and rather low melting point it is preferred, prior to applying heat and pressure, to interpose a thin sheet of paper which absorbs organic liquids and provides a path for the escape of vapours as well as protecting areas to which heat and pressure are not to be applied.

The pattern of the component or circuit need not be produced on the insulating material using a stencil. Other methods, such as offset printing may be used.

When a printed circuit has been produced in the manner described above the spaces that have been left for resistors can be overprinted. The procedure already described is then repeated using a second stencil whose cut-out portions correspond to the outline of the resistors. This stencil is applied, in register, to the once printed sheet and a graphite slurry then sprayed on. The cut-out portions should provide for slight overlap onto the conductors at the appropriate points in order to provide contacts. The further procedure is the same as for printing the silver circuit.

The above procedure may be modified by separately printing the outline of the contacting circuit and of one or more resistances in the circuit and the first heat and pressure step can then be omitted. It is also possible to reverse the procedure above outlined by first printing the resistors and then using a second stencil the outline of which corresponds to that of the required printed circuit.

Not only complete circuits but specific components such as coils can be printed in the manner described.

The invention can be used to produce various electrical components such as coils and resistances. Particular interest attaches to the production of resistances since these can be made so as to cut out portions of any desired resistance.

The value of a resistance may be expressed as

$$R = \rho \frac{.L}{W\ .T}$$

where R is the resistance in ohms, ρ is the specific resistance of the material and L is the length, W the width and T the thickness thereof. When L and W are equal i.e. the resistance is a square, R is independent of the area but varies with the thickness. Consequently the resistance can be expressed in ohms per square irrespective of the size of the square. In the prior art methods of producing coatings it has been very difficult to obtain coatings of substantially uniform and predetermined thickness and it will be appreciated from the above formula that slight variations in the value of T will considerably affect the value of R. Moreover to produce a satisfactory resistance ρ and T should be constant throughout and the value of the resistance will then depend only on its length and width.

The present invention enables printing methods such as offset printing to be employed and in these substantially uniform films are employed. Thus a metal block may be prepared of the pattern of the resistance, for example. a grid system. The block is inked with the slurry based on finely divided low conducting material such as graphite, and diluent substantially free from permanent binder. The image on the block is transferred to a rubber sheet from which it is, in turn, transferred to the plastic material. The resulting films are subject to heat and pressure treatment to form the finished resistance which has a definite fixed resistance per square. Circuit lay out will usually determine the maximum length, but, by varying the width, a resistance of desired value may be cut for insertion in a circuit and fixed into position with an adhesive or by rivetting.

The present process requires that the conductor be applied to the surface of the insulating material without a permanent binder being present. A small amount of higher boiling organic liquid or the residue of the volatile diluent being relied upon to maintain a sufficient adherence of the particles of the conductor to the insulating material and this is volatilised when heat and pressure are applied. In the product the particles firmly cohere to each other and at least the lower layers thereof are firmly embedded in the insulating material.

The higher boiling organic liquid may be so chosen as to counteract any tendency of the conductor to undergo chemical change in the earlier stages of the process. Thus when sponge silver is used a small addition of an ethanolamine may be made to prevent oxidation to silver oxide or to reverse such change, if it has occurred, during the hot pressing. However since the reduction involved is an exothermic process it is not possible to use silver oxide *per se* in the coating step.

Different circuits may be printed upon the two sides of the insulating material. The second side may have an electronic shield printed thereon.

The following Examples illustrate the manner in which the invention may be carried into effect:

EXAMPLE 1.

A block is prepared of a circuit to be printed and mounted on an off-set press having a rubber sheet for transfer. The block is inked with a slurry consisting of 70% by weight of finely divided silver, 20% of triethanolamine alginate and 10% of ethylene glycol. The slurry is transferred in the usual way for off-set printing on to a sheet of polystyrene. The print is now sprinkled with finely divided silver, then with french chalk and brushed with a stable brush which has previously been dipped in french chalk. The printed sheet is covered with a sheet of very fine rag paper and inserted in a press, the platen of which is run at 150° C. and the pressure being about 500 lbs./in.^{2}, and pressed for 0.5 second. The sheet is then removed from the press and is washed with water.

EXAMPLE 2.

A pattern of a printed circuit is applied to an electrical grade of a phenol-formaldehyde laminate by the silk screen method using a slurry containing 70% by weight of finely divided silver, 5% of monoethanolamine and 25% of methanol. The print is partially dried by infra-red heating, placed in a press and subjected to a temperature of 210° C. and 1000 lbs./in.^{2} for 4 seconds. The laminate is removed and washed.

To apply the resistors to this circuit it is printed a second time by the silk screen process the stencil employed having been cut out to leave the resistor areas uncovered and allow slight overlap on to the appropriate portions of the conductors. The slurry used is 20% by weight of carbon black, 5% of glycerine and 75% of methanol. The print is partially dried, placed in the press, covered with a sheet of very fine rag paper and then given the

same temperature, pressure and time treatment as previously. The sheet is then taken out of the press and washed.

EXAMPLE 3.

A laminated sheet, identified as "Bakelite E.5089/1," (Registered Trade Mark) and described as a phenol-formaldehyde paper laminate is sprayed with a slurry containing 70% by weight of finely divided silver, 5% of monoethanolamine and 25% of methanol through a stencil giving the pattern of the circuit required. The coating is partially dried by infra-red heating and placed in a press. By the application to the whole surface of the laminated sheet of pressure of 1,000 lbs./sq. in. and a temperature of 185° C. for 4 seconds the circuit is bonded to the laminate in the pattern desired.

EXAMPLE 4.

In Example 3 instead of applying pressure to the whole surface, a heated die having the shape of the pattern required is pressed, in register, on to the surface of the laminate. Any silver which is not fixed may be removed by washing.

EXAMPLE 5.

A silicone laminate is coated with a vinyl chloride-phenol formaldehyde copolymer in the areas to which it is desired to apply the resistors. All solvent is allowed to evaporate therefrom so as to produce a non-tacky film of copolymer upon a silicon support. To the copolymer areas there is applied, by means of spraying through a stencil, a slurry consisting of 50% by weight of finely divided carbon, 40% of ethanol and 10% of glycerine.

The laminate is placed in a press and subjected to a temperature of 180° C. and pressure of 1,000 lbs./sq. in. for 10 seconds. It is then transferred to an oven at 150° C. for 10 minutes to completely cure the copolymer.

EXAMPLE 6.

An aniline-formaldehyde resin filled with paper fibres is coated with a urea-formaldehyde varnish (20% solids in butanol-toluene mixture) and infra-red heating applied to evaporate off all solvent and to partially cure the urea-formaldehyde condensation product present in the varnish. Through a stencil resistances are sprayed by method described in Example 5. The resistances are dried by infra-red heating.

The stencil is removed and a stencil of the required circuit is fitted to the laminate and a circuit sprayed as described in Example 3 and partially dried by infra-red heating.

The laminate is placed in a press, the platen of which is heated to 180° C. and a pressure of 500 lbs./sq. in. applied to the whole laminate for 10 seconds. The laminate with the resistors and circuit produced is placed in an oven for 10 minutes at 150° C. to completely cure the condensation product.

EXAMPLE 7.

A pattern of a printed circuit is applied to an electrical grade of a phenol-formaldehyde laminate by the silk screen method using a slurry containing 70% by weight of finely divided silver, 5% of monoethanolamine and 25% of methanol. The print is partially dried by infra-red heating, placed in a press and subjected to a temperature of 210° C. and 1,000 lbs./sq. in. for 4 seconds.

To the circuit thus produced the resistors are applied by spraying firstly the vinyl chloride copolymer of Example 5 in a volatile solvent, drying and spraying a slurry of 30% by weight of carbon, 60% of ethanol and 10% of monoethanolamine through a stencil cut to the pattern of the desired resistances. The laminate is placed in a press and subjected to a pressure of 1,000 lbs./sq. in. and temperature of 180° C. for 10 seconds. The laminate is transferred to an oven and the copolymer completely cured.

EXAMPLE 9.

A sheet of silicone treated glass fibre is coated with copolymer as described in Example 5. A slurry of 20% by weight of finely divided carbon, 65% of ethanol and 15% of glycerine, is sprayed through a stencil of the required resistor pattern. The laminate is placed in a press and subjected to a temperature of 180° C. and pressure of 1,000 lbs./sq. in. for ten seconds. The laminate is transferred to an oven and the copolymer cured.

To apply the circuit to these resistors a slurry of 70% by weight of finely divided silver, 5% of monoethanolamine and 25% of methanol is sprayed through a stencil cut in the pattern of the required circuit. The coating is partially dried by infra-red heating and placed in a press. A die, in the circuit pattern desired, heated to 150° C. and accurately registered, is applied under a pressure of 1,000 lbs./sq. in. for 4 seconds. The laminate is then placed in an oven for a further 10 minutes at 150° C. to complete the curing of the copolymer.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A process for producing a printed electrical element which comprises applying to the surface of an organic electrically insulating material a pattern of an electrical conducting path as a coating,

substantially free from any permanent binder, of a finely divided electrical conductor and thereafter simultaneously applying heat and pressure to at least the coated areas whereby the individual particles of conducting material cohere together to form said conducting path at least partially embedded in the underlying insulating material.

2. A process for producing a printed electrical circuit which comprises applying to the surface of an electrically insulating material a pattern of the conducting path of the circuit as a coating of an electrical conducting metal, in finely divided form substantially free from any permanent binder and thereafter simultaneously applying heat and pressure to at least the coated areas whereby the individual particles of conducting metal cohere together to form said printed circuit at least partially embedded in the underlying insulating material.

3. A process for producing a printed electrical resistance which comprises applying to the surface of an electrically insulating material the pattern of the conducting path of the resistance as a coating of a poor electrical conductor, in finely divided, form, substantially free from any permanent binder and thereafter simultaneously applying heat and pressure to at least the pattern covered areas whereby the individual particles of material form a low conducting path at least partially embedded in the underlying insulating material.

4. A process for producing a printed electrical circuit which comprises applying to the surface of an electrically insulating material a pattern of the conducting path of the circuit as a coating of an electrical conducting metal in finely divided form substantially free from a permanent binder, also applying to the surface the pattern of the conducting path of at least one resistance as a coating of a poor electrical conductor in finely divided form substantially free from any permanent binder, and thereafter simultaneously applying heat and pressure to at least the coated areas of the insulating material whereby the individual particles of the conducting materials cohere together to form conducting paths at least partially embedded in the underlying insulating material.

5. A modification of the process of claim 4 in which a printed electrical circuit is produced by the process of claim 2 and at least one printed resistance is thereafter produced thereon by the process of claim 3.

6. A modification of the process of claim 4 in which a printed resistance is produced by the process of claim 3 and a printed circuit is thereafter produced by the process of claim 2.

7. A process according to any of the preceding claims in which the organic electrically insulating material is an electrical grade of a phenol-formaldehyde or aniline-formaldehyde resin, an aminoplast resin, a polyacrylic resin, a polyvinyl resin or polythene.

8. A process according to any of the preceding claims in which the conductor is applied to the insulating material as a slurry in a volatile diluent.

9. A process according to claim 8 in which in addition to said volatile diluent, the slurry includes a small proportion of a less volatile organic solvent.

10. A process according to any of claims 1 to 7 in which the conducting material is applied to the insulating material by printing technique, such as offset printing.

11. A process according to any of the preceding claims in which the organic electrically insulating material is a thermoset material and a temperature of the order of 200—250° C. and a pressure of the order of 1000—2000 lbs./in.^{2} are employed.

12. A process for producing a printed electrical element substantially as hereinbefore described with reference to any one of the Examples.

13. Printed electrical elements whenever produced by the process of any of the preceding claims.

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For

WARD, BLENKINSOP & COMPANY LIMITED, PETER PAUL HOPF and RONALD EDGAR JOHN LISHMUND,

Stevens, Langner, Parry & Rollinson,
Chartered Patent Agents,
5/9, Quality Court, Chancery Lane,
London, W.C.2, and at
120, East 41st. Street, New York 17,
New York, United States of America.